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SICK BOAT SYNDROME

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ABSTRACT

Many pathogenic micro-organisms are likely to attack passengers of cruise ships and other vessels or travel between continents as a peculiar type of a "stowaway". The epidemiological tests conducted since 1987 with regard to watercraft led to the coining of a term known as the Sick Boat Syndrome (SBS). The main illnesses encountered on watercraft include gastrointestinal diseases (foodborne) and Legionellosis. Additionally, the ventilation and air-conditioning systems of old commercial ships (the so-called Tramps) constitute a real technical challenge. Conditioned air (with removed undesired odour and micro-organisms) should constitute ca. 25% of circulating air. In practice this situation is not typical for vessels of this class. Unclean air poses a real hazard for the crew.
Key words: Gastrointestinal diseases, Norwalk virus, Legionella, Sick Boat Syndrome.

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INTRODUCTION

The epidemiological studies conducted in the 1980s led to the coining of a term referred to as "the Sick-Building Syndrome" [1]. A parallel term was also "the Sick House Syndrome" [2]. The said syndromes are analysed separately, although the work by Runeson-Broberg and Norbäck [3] compared the quality of air with the psychosocial conditions in a workplace with regard to both of them. The study encompassed 1000 subjects aged between 20-65 years. By logistic regression method [4], low quality air in a workplace, low quality training in health and safety regulations were correlated in relation to age, sex, smoking and body mass index (BMI). Moreover, the occurrence of such symptoms as headaches, fatigue, nausea and feeling cold was taken into account. It was explicitly confirmed that the occurrence of the discussed syndromes is positively correlated with air contamination and low quality health and safety protection in a workplace.

In 1987, Christenson et al. [5] used the term Sick Boat Syndrome (SBS) in their work. The name provided an adequate description of the epidemic of infectious diseases which took place in 1984 among the passengers of a cruise ship travelling along a line connecting Southern Europe with Northern Africa. The majority of symptoms were connected with gastrointestinal and respiratory illnesses.

Among 295 sick passengers, 88% presented flu like symptoms, with 20 cases of infections of lower respiratory airways. Among the 24 cases of viral infections, 14 were connected with type B flu virus, whereas the other were classified as type A flu viruses, RSV viruses and Epstein-Barr virus. 81 patients were examined for the presence of Legionella antigens. In two cases, the antibody titre amounted to 128, whereas among 16 and 32 patients the titre was equal to 64 and 32 respectively.

It was confirmed that the epidemic was caused by contact with numerous pathogens, mainly those connected with infections of the upper respiratory tract. A single common source of infection was not identified.

In 2009, the global commercial fleet consisted in the total of 53 005 vessels, with 31% being traditional cargo ships, 27% tankers, 15% bulk carriers (e.g. for coal), 13% passenger liners, 9% container ships and 5% other vessels. It is estimated that over one million people are employed on commercial ships, spending there entire months in conditions which often remain beyond any control of sanitary services.

In 2010 over 20 million passengers were transported by ships and ferries.

According to Elain H.Cramer [6] in 2002, the VSP system (Vessel Sanitation Program of the Centers for Disease Control and Prevention) noted 29 cases of epidemics of gastrointestinal diseases among ship passengers and crews (symptoms noted in 3% or more passengers) as compared with 3 cases of acute gastrointestinal infection in 2001.

Also the naval vessels of particular fleets consists of watercraft often operated by over 5000 people. Such personnel concentration on a relatively small area creates certain behaviour and intensifies the phenomena of an epidemic character [7]. The main illnesses encountered on watercraft include gastrointestinal diseases (foodborne) and Legionellosis.

GASTROINTESTINAL DISEASES

Many pathogenic micro-organisms are likely to attack passengers of cruise ships and other vessels or travel between continents as a peculiar type of a "stowaway". An example of such a "stowaway" is an Asian mosquito (of *Aedes* genus), the so-called tiger mosquito, which in 1985 travelled to the USA in a load of used car tires. In less than two years the mosquito, transferor of such diseases as yellow fever or Denga disease, managed to disseminate over 17 States of the USA [8].

The majority of gastrointestinal diseases occurring on ships and vessels are connected with water and food. The sources of pathogenic agents are infected fresh water containers, improperly disinfected water systems, water collection from unknown sources, absence of sanitary checks of food preparation and storage areas, etc.

The Norwalk virus (NLV) is one of the most common causes of gastrointestinal diseases. The virus belongs to calicivirus family, the so-called SRSVs (small round structured viruses), encountered for the first time during non-bacterial infection epidemic among schoolchildren in Norwalk, Ohio, USA. The symptoms include: nausea, vomiting, diarrhea and abdominal cramps. The incubation period reaches between 12 and 48 hours. Other, rarer symptoms include: headache, fever, shivers and muscle pain. Common therapy involves rehydration and replenishment of electrolytes (preventing dehydration). Virus transmission is realised in the faeces – food cycle. The infectious dose has not yet been determined, however it is believed to be very low. Specific diagnostics is carried out only by some laboratories and encompasses electron microscopy analysis, PCR and serological techniques.

Water is the main source of infection, including urban fresh water containers, pools, as well as water stored on ships and vessels. The infection is most likely to affect the personnel of fish and food industry (sea food and additives to salads are common sources of infection), as well as employees of sewage treatment plants. It is estimated that only the flu virus infection is comparable in its scale and scope to Norwalk virus. It mainly affects patients of hospitals, elderly care homes, people staying in prisons and schoolchildren. In the USA it was assessed that over 50% of population over the age of 18 indicated presence of NLV antigens. Immunisation against this virus type is not permanent and numerous cases of infection recurrence have been noted. Also, the disease is more likely to affect young people and adults.

Numerous cases of NLV epidemics were observed in military units and among vessel crews, including the so-called "mysterious disease" of the British soldiers deployed to Afghanistan [9].

Tab.1.

Examples of gastrointestinal epidemics in the years 1990-2013.

Year	Location	Transferring agent	Description	Comments Data source
1991	Peru, South America	Water	Water used to fill the ballast containers on a ship returning from a cruise to Asia was infected with *Cholera* vibrio.	Cholera epidemics spread to Central America. Approximately 11 000 people died [10].
1998	Passenger liner	Infected water or food	640 passengers (80%) of a cruise ship were infected with NLV.	[8]
1998	Naval ships	Infected water or food	200 crew members (20%)	[8]
1997	Naval ships	Infected water or food	1806 crew members (43%)	[8]
2002	Grand Canyon, USA	Water flowing into Colorado River from Glen Canyon Damp water treatment plant.	130 tourists participating in a canoe trip across the Grand Canyon. Nausea, vomiting and diarrhoea	Laboratory testing confirmed Norwalk virus infection. Virus resistant to chlorination. The first NLV case in a public water supply system [11].
2002	Passenger liner, USA, Florida	Water, oysters	180 passengers and 28 crew members of "Amsterdam" ship	Liner disinfection with VIRKON.1% preparation, stabilised peroxides solution with high detergent content.
2002	Military personnel of the British mission in Afghanistan	Infected water or food	29 soldiers with symptoms including diarrhoea and vomiting were transported to Germany and England.	A very short period of disease development. Infection during travel by sea. Diagnostic difficulties.
2009	Princess Cruises, *Coral Princess*	Infected water or food	271 passengers infected with E.cola virus and NLV.	
2009	Carnival Cruise Line, *Carnival Liberty*	Infected water or food	265 infected passengers.	The liner was subjected to cleansing and thorough disinfection upon arrival in Miami. It resulted in a delay of passenger boarding.
2010	Celebrity Cruises, *Mercury* , February 2010	Infected water or food	443 passengers infected with NLV.	See below
2010	Celebrity Cruises, *Mercury* , March 2010	Infected water or food. Contact with infected passengers or crew members	419 passengers with acute symptoms of a gastrointestinal infection.	The incident occurred 30 days after an analogous epidemic on the same vessel in February 2010. Multiple objections of sanitary-epidemiological services regarding the cleanness maintenance procedure of cruisers of this line were confirmed

Tab.1. cont.

Examples of gastrointestinal epidemics in the years 1990-2013.

Year	Location	Transferring agent	Description	Comments Data source
2012	Princess Cruises, *Crown Princess* , February 2012)	Infected water or food. Contact with infected passengers or crew members	In total 363 passengers and crew members infected.	The cruise was shortened by two days due to numerous cases of acute gastrointestinal infection
2013	Celebrity Cruise Lines, *Celebrity Summit* , August 2013)	Infected water or food	335 infected passengers	Patients with symptoms of acute gastrointestinal infection, abdominal pains, vomiting and diarrhoea were subjected to quarantine in their cabins for the purpose of reducing dissemination.
2013	Princess Cruises, *Ruby Princess,* March 2013)	Infected water or food. Contact with infected passengers or crew members	276 infected passengers	After the ship returned to Fort Lauderdale in Florida from a weekend trip across the Caribbean, new passengers were boarded with a significant delay due to necessity to carry out comprehensive ship disinfection ordained by the CDC.

LEGIONELLOSIS

Legionellosis is a potentially serious pneumonia, first observed in 1976. The bacterium, later called *Legionella*, infected 221 participants of a reunion of the American Legion (veteran association), leading to the death of 34 people due to acute pneumonia.

Legionella pneumophilla is one of over 30 species from this genus which are currently recognised in the world, of which at least 19 are known to cause pneumonia in humans.

Legionella occurs commonly in small concentrations in surface waters, lakes, rivers. The pathogen can move from natural into artificial reservoirs, air-conditioning systems, fountains, etc. The optimum water temperature for its development ranges between 20^0 – 45^0 C. *Legionella* can survive in fresh water kept in room temperature for over a year. The presence of other micro-organisms, algae, amoebas, bacteria and materials facilitating growth of micro-organisms (rust, sludges) is conducive to pathogen development.

The disease course is similar to the flu, with dry cough and developing symptoms of pneumonia. Fever with shivers usually appears after 24 hours, with body temperature exceeding even 40^0 C. Moreover, approximately 30% of patients manifests the symptoms of diarrhoea and vomiting, as well as fluctuating consciousness. The incubation time reaches between 2 – 10 days.

Legionellosis spreads through inhalation, thus infecting the respiratory airways with water-air aerosol. The smaller the droplets, the greater the risk of infection. Droplets of the diameter of 5μm easily infect lower respiratory tract. Bacteria transmission between humans was not noted.

Etiological diagnosis is determined on the basis of positive bacteriological screening of blood and aspirants from the lungs, albeit the growth of *Legionella* bacilli is difficult and requires proper media. Furthermore, determination of bacteria content in water requires great caution and access to suitable laboratory equipment. Tests can be also performed with the use of ELISA immunoassays.

The risk of infection increases with age (particularly > 50 years of age) and mainly affects males, individuals with reduced immunity, smokers and alcoholics.

In the case of development of an epidemic, it is crucial to define the source of infection. Laboratory-confirmed infection of water sources requires activation of chlorine disinfection procedures, increasing the temperature of circuit water to 60^0 C (at least for a time until pathogen reduction to less than 95% of the initial value). It is moreover required to replace old ventilation and water systems (rust).

Tab. 2.

Examples of infection with *Legionella* baccili in the years 1994-2004.

Year	Location	Transferring agent	Description	Comments Data source
1994	Passenger liner	Water in the hydromassage system	50 passengers	1 person died [8]
1996	Cargo ship	Drinking water and air-conditioning	Microbiological inspection revealed presence of *Legionella pneumophila* in water	[8]
1998	Passenger liner	Water circulation system	After two cases of Legionellosis microbiological water inspection was carried out confirming a high concentration of *Legionella* baccili.	Having been presented with analysis results the captain of the ship ordained consumption limited to bottled water only. Circulating water was heated to the temperature above 55^0 C guaranteeing removal of *Legionella* baccili. Upon the arrival to port, a 2-day disinfection of water circulation system was conducted [12].
1999	Whole Europe	Water circulation system	289 laboratory-confirmed cases of Legionellosis.	Collective data regarding 17 countries. [13] 18 people died.
2001	Norway	Air conditioning systems	13 infected persons of whom two died	Stavanger, a city with the population 100 thousand, employee base for platforms located in the North Sea [14].
2002	Japan	Hot springs	223 infected persons of whom 6 died	A newly opened recreational centre - Sun Park Hot Springs [15]
2003-2004	Passenger liners. The Caribbean region. collective data	water	8 infected persons of whom 2 died	CDC Report [16]

SICK BOAT SYNDROME VS AIR QUALITY

Each visit to a small vessel, particularly that equipped with a diesel engine, involves experiencing of a specific kind of unfresh air. The ventilation and air-conditioning systems of old commercial ships (the so-called Tramps)constitute a real technical challenge. Conditioned air (with removed undesired odour and micro-organisms) should make up ca. 25% of circulating air. In practice this situation is not typical for vessels of this class. Unclean air poses a real hazard for the crew. Even slight leaks in the waste collection and disposal system cause the air in circulation to be invaded with viruses, bacteria, methane and hydrogen sulphide evoking the characteristic stench of an old engine room. The air circulating in such watercraft can contain:

Mould – mould spores are to be found everywhere. Limited air movement, humidity and numerous nourishment sources make machinery spaces an ideal environment for mould growth. Nourishment sources include leather, paper, fabrics and in particular, wool. Thus, it comes as no surprise that after a 10-15-day cruise, especially in tropical conditions, clothing, bed linens and other textiles may be covered in mould.

Volatile organic compounds, VOCs – sources of their emission include diesel engines, oils, plastic furnishing elements, etc.

Listeria monocytogenes- this unique bacteria strain may survive in a very cold atmosphere and is often found in dehumidifiers, ice generators and refrigerators, as well as U-bends in showers and washbasins.

Norwalk virus – the most common source of infection with gastrointestinal symptoms. The most probable contact areas with the virus are dirty hands and contaminated surfaces.

Staphylococcus bacteria- there are many staphylococcus strains, however the most important one is staphylococcus aureus (*Staphylococcus pyogenes var.aureus*). Pathogenic staphylococcus may be found on the skin and in the nasopharynx of 30-40% of healthy people. The door leading towards an infection is most commonly the skin and mucous membranes.

The most drastic effect of an encounter with type A streptococcus (also referred to as flesh-eating bacteria) with a human organism, namely the **nercrotizing fasciitis** (Fasciitis necrotisans), constitutes a relatively rare infection of subcutaneous tissues with polymicrobial etiology, affecting fascia and the surrounding tissues. Tissue necrosis is a result of ischemia invoked by the thrombosis of subcutaneous tissues. The infection usually develops in people with immunological disorders resulting from various factors. Due to its rapid development the infection often results in a patient's death. Early detection and immediate surgical intervention accompanied by antibiotic therapy has a decisive impact on medical prognosis.

All of the above microbiological hazards may be limited or completely eliminated through the implementation of proper procedures aimed at the improvement of air quality on watecraft. The proposed procedures include:

- active oxidization of air pollutants, for instance, by the installation of devices produced by the RGF company (advanced oxidation technology) fig. 1,
- active oxidation of vapour produced by fuel filtration system.

Both procedures of removal of dangerous vapour are based on catalytic combustion technique, which by generating active oxygen compounds on the probe, with the capacity of 99%, removes from the circulating air mould, viruses and bacteria, as well as residual diesel vapour.

Fig. 1. Catalytic probe cleansing the air in circulation.

PREVENTION VS SICK BOAT SYNDROME

For the purpose of prevention of spread of micro-organisms causing the abovementioned diseases, in 1970 the CDC (Centre for Disease Control and Prevention, Atlanta, USA) implemented the Vessel Sanitation Program encompassing all passenger liners carrying 13 or more passengers and making a stop in one of the American ports. Analogous guidelines concerning sanitary-hygiene vessel inspection (included in VSP) become the basis for recommendations regarding sanitary-hygiene inspection of the US naval fleet.

The inspection should be conducted twice a year by an independent team of inspectors and cover complete analysis of critical sanitary inspection points (100 points). A vessel meeting the basic sanitary inspection criteria should receive the minimum of 86 points. A result below 86 means that the inspection will be repeated within 30-45 days. Inspections are carried out by 2 inspectors together with an appointed ship officer. The inspection encompasses:

- water circulation on a ship, drinking water production system, containers,
- air-conditioning and shower system,
- food, reserves, thermal processing, kitchen ventilation system,
- possible points of food contamination,
- crew's hygiene,

- deratting inspection,
- health status of the crew (preventive examinations, parasitological examinations, narcotics, CDT),
- status of health documentation, water and food inspection log.

Poland, being a member state of WHO, is obliged to implement the requirements established by WHO in the year 2005 in the form of a document entitled IHR 2005 (International Health Regulation 2005). The document determines modern principles of epidemiological surveillance and fast and adequate reaction to the risk of dissemination of infectious diseases [17,18].

The adopted legal regulations concerning ports, airfields and border crossings on the land encompass:

- evaluation criteria of hazards related to human and cargo transportation,
- conditions to be met by border quarantine and health examination facilities,
- certification procedures for airplanes and ships,
- certification procedures for ports and airfields.

Countries associated in the World Health Organisation (WHO) were obliged to commence the process of implementation of principles included in the IHR 2005 at the beginning of June 2007. The created uniform network of criteria, principles and reactions to microbiological threats should strengthen the capabilities of particular countries to detect and prevent dissemination of infectious diseases both on a local and international scale. For this purpose the principle of real time detection and reaction was adopted. Particular member states of WHO were to achieve satisfactory level of epidemiological surveillance operating in real time within the period of 2 years, and the optimal level within the period of another 3 years.

In accordance with articles 20, 27, 39 and Annex 3 to primary IHR 2005 document, as of 15 June, 2007, Ship Sanitation Control Exemption Certificate / Ship Sanitation Control Certificate (SSCEC / SSCC) also became effective. The said certificate is a replacement to Deratting Certificate/Deratting Exemption Certificate (DC/DEC) applied pursuant to IHR convention since 1969. After 15 June 2007 the issued SSCEC/SSCC certificates were valid only for 6 months with the possibility of their prolongation by 1 month if a ship was unable to pass proper inspection in a given port. During the additional month a ship was to undergo sanitation control in a port fulfilling inspection requirements in accordance with IHR 2005 (Annex 3).

The discussed IHR 2005 principles impose on the member states of WHO an obligation to work out detailed guidelines for sanitary-epidemiological conditions to be met by ships, vessels, passengers, crews and goods transported by them in order to reduce to absolute minimum the possibility of dissemination of infectious diseases via sea transportation.

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